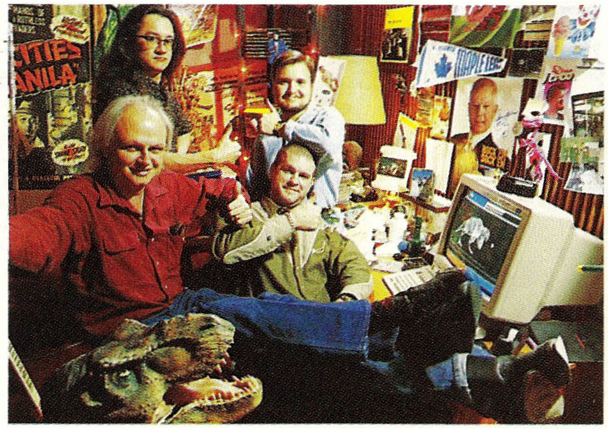
ILM's Digital Dinosaurs Tear Up Effects Jungle

"The point is not to push the technology, the point is to make a movie," according to Dennis Muren.

by Ron Magid

Can a film foment a revolution? The techno-wizards of northern California's Industrial Light & Magic caused the effects world to undergo a seismic shift in 1977, when the company was originally formed by George Lucas to create effects for *Star Wars*. What that film did for motion-control photography, *Jurassic Park*, Steven Spielberg's much-anticipated screen version of Michael Crichton's cautionary tale of runaway science and genetically engineered dinosaurs, promises to do for computer-generated imagery. As one tongue-in-cheek sign ("Ye Olde Historic Motion Control Stage") at the ILM facility indicates, the fast-approaching computer effects age threatens to usurp even that hallmark of the ILM legacy, forever replacing the crude but wondrous techniques of the past with the sophistication of the video screen.



This breakthrough in computer technology threatens to leave a trail of fossils in its wake, including the beloved technique of stop-motion animation, and, to a lesser degree, full-scale animatronic puppetry. These suddenly outmoded techniques were once the cornerstones upon which *Jurassic Park*'s effects were based. Spielberg originally hired Stan Winston to fabricate full-sized animatronic dinosaurs for principal photography, while stop-motion effects giant Phil Tippett was to handle the Go-Motion puppetry of miniature rubber dinosaurs articulated via traditional ball-and-socket armatures. Industrial Light & Magic was to add motion blur to Tippett's creatures' movements. "I wasn't terribly thrilled about that idea," admits ILM's Dennis Muren, who, along with Mark A.Z. Dippe, served as *Jurassic Park*'s visual effects supervisor. "It seemed like a lot of work for something that always was going to fall short."

Ironically enough, when forces within ILM lobbied to use computer-generated imagery instead of Tippett's puppet animation, it was Muren, the man who had supervised the breakthrough computer effects for James Cameron's *The Abyss* and *Terminator 2*, who remained skeptical about using CG to create living, breathing dinosaurs. After all, the CG water tentacle and chrome man created for those films were both very different from the flesh-and-blood behemoths required for *Jurassic Park*. "We backed into it slowly because there was already a whole approach being taken with full-sized and Go-Motion dinosaurs," ILM's towering, white-haired, senior mad scientist recalls. "We needed to deliver our shots on time, and we didn't know how real we could make them using CG. I'd never seen the problems solved with the blends and the geometry where shoulders or elbows joined seamlessly. That stuff's incredibly serious; you can't have that in a major movie, even though some CG people might say it's okay. We're not making CG here. The point is not to push the technology, the point is to make a movie. That's why I took this thing really slowly. I set the challenge: 'You've got to prove to me that we can pull this off before I go to Steven.' From then on, I'd see tests and point out problems we still needed to solve. There were a lot at every step."

Visual effects co-supervisor Mark A. Z. Dippe, a prominent member of ILM's next generation of up-and-comers, eagerly picked up Muren's gauntlet. "I was a total believer," the youthful Dippe says vehemently. "My attitude was, 'Let's take some risks and make some new types of images.' I felt computer animation would give us much more freedom than puppet animation. Stop- or Go-Motion puppets have very restricted movements because the puppets have

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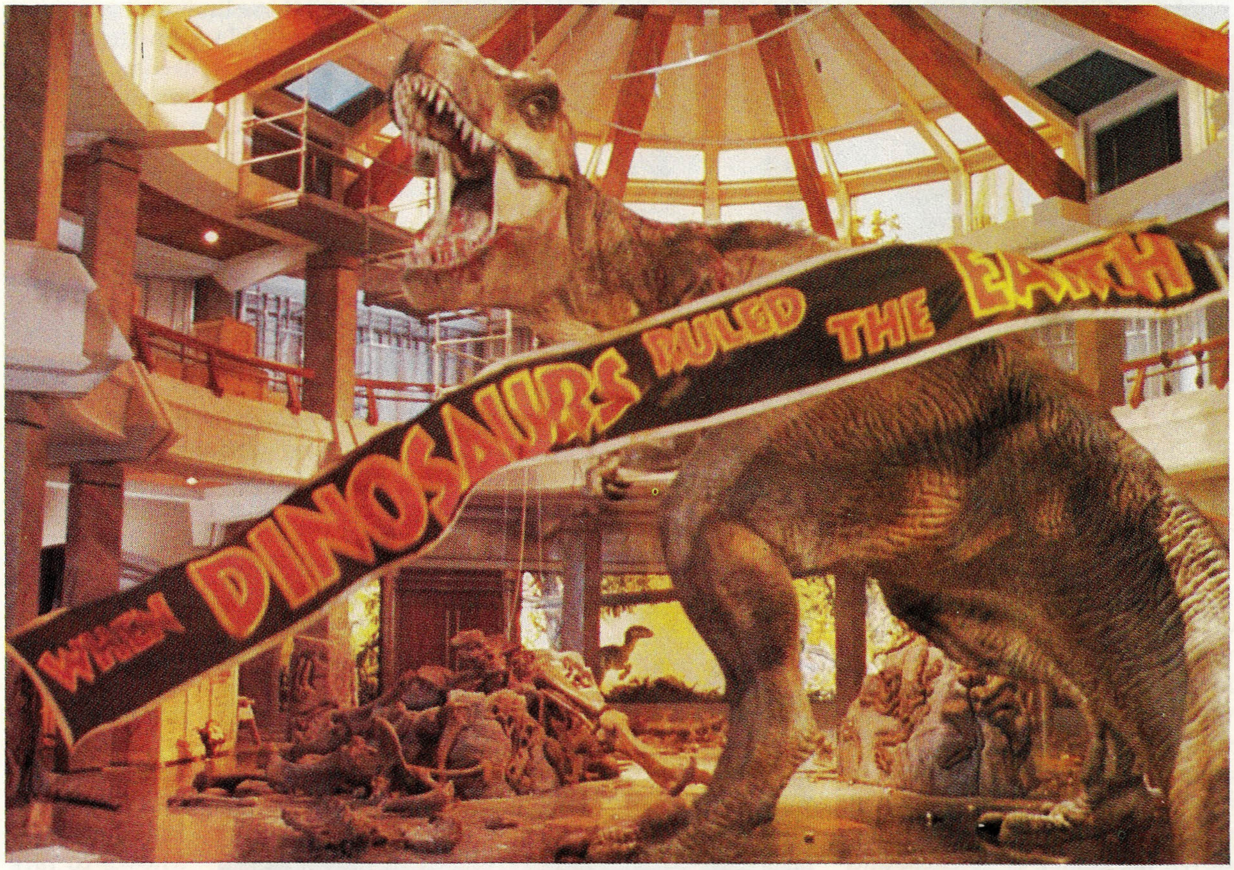


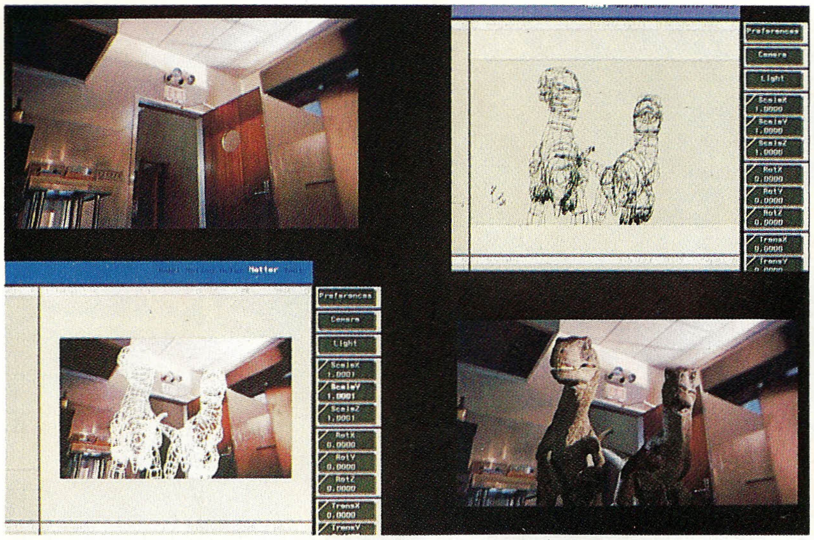
Opposite: ***Shaking up the effects world, clockwise from lower left, are: ILM senior visual effects supervisor Dennis Muren, ASC;*** **Jurassic Park** ***visual effects co-supervisor Mark Dippe; lead animator Eric Armstrong; and animator Steve Williams.*** **This page:** ***A computer composite that says it all.***

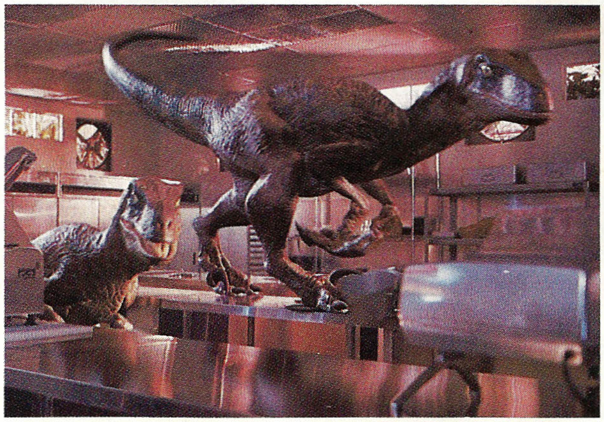
to be supported by a physical rig. It's almost impossible to get your dinosaur to fall down and roll over, because you can't get the rig to do that very easily. In the computer world, we have total freedom of movement, and we can also simulate all of the attributes of a living dinosaur, like muscle, bone, skin, sweat and blood. We can't do those things very well with a latex creature. I felt that by using CG, we could make our dinosaurs run and jump and fight, and we could have herds of them! But there was still a lot of doubt on Dennis' part."

In December of 1991, Dippe enlisted the aid of his friend Steve Williams, and together they set out to prove that CG was the best way to bring *Jurassic Park*'s dinosaurs to the screen. Williams, who seems more at home on a Harley than behind a computer, is a graduate of Sheridan College, Disney's East Coast training school. Though his background is primarily in cel animation, he intuitively grasped that the two-dimensional world of cartoons and the three-dimensional realm of the computer were oddly similar. "If it doesn't work in 2-D, it won't work in 3-D," he says with a grin. "Dennis knew that Phil Tippett's shop was on this *Jurassic Park* project, but he also knew that if he let this little wild pack of dogs, namely me and Mark Dippe, loose on this CG problem, we'd solve it. I figured the easiest thing to do was to make a tyrannosaurus rex skeleton and animate it, so I had my brother-in-law send me down the complete schematics of an 18-foot T-rex from the Tyrell Museum in the badlands. I just scanned that in and began building bones in the computer, using the Alias modeling system, until I had put together a rex. Next, I had [Lead Technical Director] Stephen Fangmeier do a render of it on a rotating table using the RenderMan program so we could all look at it. It looked like a real T-rex skeleton, with shadows and all of the correct fluting on the skull and so on. Then I used SoftImage and did a walk cycle on it and everyone freaked out."

After the film's producers, Kathleen Kennedy and Frank Marshall, saw Williams' test, they agreed it was time to show the results to Spielberg. They also offered to give ILM's guerilla unit some additional funds to test a sequence of gallimimus, as well as to build a convincing skin on top of the bones. By this time, six people were working on the task. Dippe and Williams took Stan Winston's ⅕-scale tyrannosaurus rex maquette (which ironically was slated to become the Go-Motion animation puppet) to Cyberware, where the sculpture was sliced into cross-sections and laser-scanned onto a computer disc. "I took the data back to ILM, where I remade it and fit it together so we could use it," Williams recalls. "It was inefficient for me to take the direct data and try to build a rex in the computer, but I could use Winston's model as a template to make what was essentially a digital wireframe puppet of a T-rex."

Right: ***A look at the four stages needed to create the raptors' invasion of the compound kitchen. At upper left, a clean plate; at upper right, a wireframe rendering of the raptors; at lower left, the wireframe placed in the plate; at lower right, the completed frame (screen courtesy of SoftImage).*** **Below right:** ***A shot of the raptors on the move, complete with impeccable highlights and skin details.***





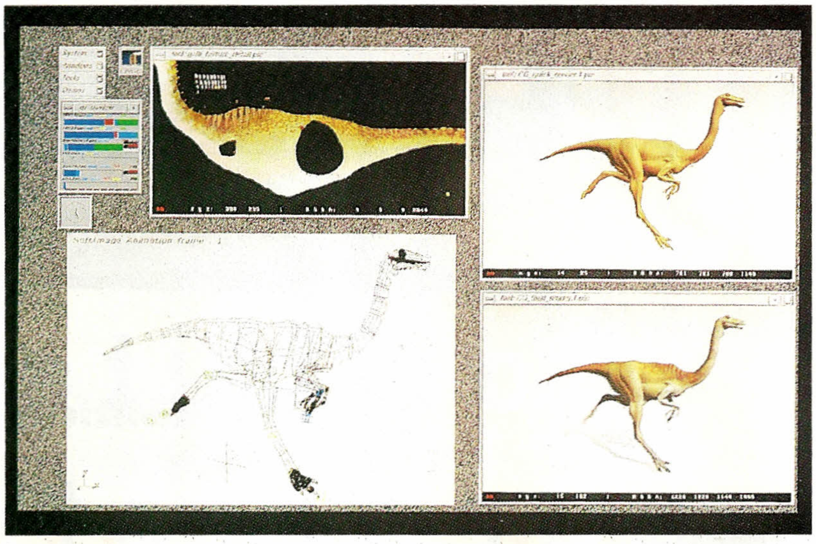
The digital T-rex looked like a cross between a sculptor's armature and a topiary animal, using vertical and horizontal loops to create a rough three-dimensional puppet, or "wireframe." The wireframe creature's arms, legs, head and tail were knitted together using a four-sided patch with seams meeting down the center of its chest and tail, around its neck and underneath each arm and leg to create a smooth, continuous surface. This model was still a far cry from a convincingly lifelike tyrannosaurus, however. "Stan Winston's T-rex sculpture was beautifully done but static," observes effects supervisor Dippe. "It gave us what we called our 'null position,' but there was so much more to do; we had to skin it and make it move. It was as if we had to take a single photo-realistic still and turn it into a moving, photo-realistic film."

Once the wireframe puppet had been made whole, it was time to complete the topiary creature's transformation into a living dinosaur by covering it with a texture-map skin. For *Jurassic Park,* ILM developed a much simpler, more effective way to skin a wireframe dinosaur: a system called 3-D Paint, which Williams and Stephen Fangmeier used to dress their T-rex. "Normally, we create a texture map by painting on a flat surface in the computer, and then the computer wraps that texture around our wireframe creature," Williams explains. "It's like working on a bearskin rug which the program then wraps around a wireframe bear. With 3-D Paint, we could look at our dinosaur from any point of view and then paint directly on its texture-map skin after it was wrapped around the creature. That way we could do our final retouching directly on our 3-D creature from the POV of the camera in any given shot."

But the T-rex needed an additional layer of detailing not found in most CG creations: wrinkles. While some of the major folds were built into the actual wireframe geometry, a myriad of smaller wrinkles, which had to ripple with each movement, were added by using a new technique called enveloping. "It's essentially the same bearskin rug," Williams says, "only covered with all these lines and wrinkles. Wherever a black line fell on the surface of the creature, the skin indented, and wherever a white line fell, it made a crest, which gave us the correct elephantlike skin for the rex."

The animators also wanted the T-rex's loose skin to jiggle the way an elephant's does when it moves. "We wanted to take the skin to a new level of believability," Williams says, "so we covered it with a whole bunch of invisible points and cross-sections, and we actually inserted little spheres under the skin that shook and shimmered whenever the dinosaur took a step. Each point, cross-section and sphere had a name and address, so a sphere in quadrant five on the leg muscle knows to talk to point number 18 on the skin over the T-rex's kneecap. That way, when the sphere on the leg shimmered at every step, the skin over the kneecap oscillated just a little as well."

After Spielberg witnessed Williams and Fangmeier's skinned T-rex test, the director was determined to have ILM do not only the herd shots, but all of the dinosaur effects that were originally to have used Tippett's Go-Motion technique. Phil Tippett would remain on the project as animation director; his facility, Tippett Studio, would interface with ILM through a system Muren and Tippett had conceived called "DID," or Digital Interface Device, which utilized an actual stop-motion armature linked to a computer. It was hoped that by using this mechanism, Tippett and company could animate their wireframe T-rex shots and then pass them back to ILM, where skin and texture maps would be added before



Right: ***Rendering a gallimimus. At upper left, a texture map of the creature's skin; at lower left, a SoftImage animation frame; at upper right, a "quick render"; at lower right, the final rendering with motion blur and shadow.*** **Below right:** ***Actor Sam Neill attempts to evade a charging herd of gallis in one of the film's most demanding — and groundbreaking — special effects sequences.***

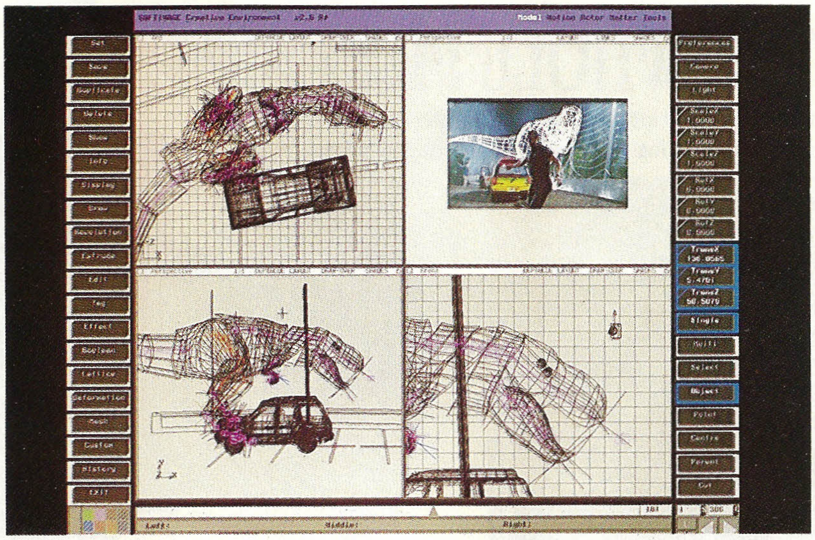
they composited the creature into the background plate. (Another important consideration, of course, was cost-efficiency; if the CG effects had proved more expensive than stop-motion, the experiment would have been aborted.)

Visual effects supervisors Muren and Dippe rapidly assembled a team of CG animators of varied backgrounds. Using Stan Winston's maquettes of his full-scale creatures and other dinosaurs that would only appear in the film via computer animation, the ILM team soon had a miniature brachiosaurus, velociraptor and gallimimus, among other creatures, scanned into their computers and ready for work in the digital realm. Muren had worked with Winston before on *Terminator 2*, and found the experiences comparable: "In both cases, our work had to follow Stan's because his stuff was needed on set while our work began after production ended. Working in postproduction, it was really important to focus on the shots we had to make, not on the whole deal. We delayed as much as possible on each sequence, hoping to get the final cut so that all our time and money could go into those shots that were definitely in the sequence."

ILM's CG dinosaurs not only had to be well-rendered, they had to match Winston's full-scale creatures exactly, wrinkle for wrinkle and bump for bump. "Because of all the bumps and folds of skin, it had to be a dead match," Muren says, shaking his head, "and that's hardly ever been done. Phil Tippett had input on the coloring and the final finish on all of them. We couldn't use our usual procedures for generating random surface detail because these things had to be very specific in order to cut."

More importantly, the creatures had to move believably, which meant that Muren, Dippe and the rest of the team had to become dinosaur psychologists. "Stan Winston and his crew deserve a tremendous amount of credit for designing the animals," Dippe says, "but we did a tremendous amount of work to bring them to life, and the way we did it was very sophisticated. Animation is where everything can fall apart; the creatures can easily look stiff and move as if they don't have a center of gravity. To counter that, we had a local performance artist, Leonard Pitt, come here and give us classes every week in performance, dance, movement and even mask work, just to get into the whole idea of how these creatures moved. We tried to find the tempo of their movements, to see how they shifted their body weight. We also played with things that were more serpentine, like the motion of their tails. We went out and took footage of elephants and rhinos at Africa U.S.A., and applied those movements to our CG dinosaurs. We also studied footage of Komodo dragons, who move very straight and stiff and whose bodies are kind of tight, as well as ostriches, because some dinosaurs' movements were very birdlike. We all became quasi-dinosaur experts, and then we took our theories to three paleontologists. They criticized us conceptually until we showed them our animation, and then all three of them said, 'You know something? That looks so great, we may be wrong!'"

The biggest debate centered on how fast the tyrannosaurus rex would run in the "jeep chase" sequence, which, not surprisingly, was the first major T-rex sequence animated by ILM for the film, and which incorporated some of the original test footage. "That was the most demanding T-rex sequence," claims Dippe, who supervised it. "The T-rex runs after the jeep, crashes through a huge log blocking its path and does other things that a six-ton animal would have a hard time doing. But we had to make it believable. The jeep was moving at twenty miles per hour and the T-rex had to catch up to it.



Right: ***A shot of actor Jeff Goldblum standing in front of an irascible T-rex involved shooting a clean plate, making a wireframe of the T-rex in Alias, animating via SoftImage software (shown here) and combining the various elements in a final composite.*** **Below right:** ***A more detailed look at Goldblum and the wireframe menace.***

What was fun about it was that we'd totally created this creature and had to think as if we were it. What's its motivation? 'I want to kill that [expletive deleted]! I'm mean, I stink, my breath is really bad, I weigh seven tons and I run twenty m.p.h., but I run on two legs and I take three steps to stop, and if I fall down, I'm going to break my neck!'"

Steve Williams, the primary animator on this sequence, faced the unenviable task of determining not only how a T-rex ran, but how fast. "We had a zillion arguments about it," he laughs. "Some people argued that it was probably like a lion: it never ran unless it had to, and if it ran, it would do so for a short period of time and move very fast. Using that logic, I had to throw physics out the window and create a rex that moved at sixty m.p.h. even though its hollow bones probably would have busted if he ran that fast. There was also the school of thought that the thing was so big and muscular, it didn't matter whether it ran or not. Either way, there was no real reference for a seven-ton bipedal animal running around, so we had to invent a dinosaur and try to make it look believable."

"Phil Tippett and I debated about just how fast or slow the T-rex should move," Dippe says. "We wanted the dynamism and excitement and terror of the shot, which was related to speed, but we found ourselves fighting two things: if the T-rex moved too fast, he started looking light and small, while if it moved really slowly and the ground shook with every step, he looked really heavy and gigantic but ponderous."

In order to give the behemoth the feeling of size and power, yet still make it capable of catching the speeding jeep, Dippe and Tippett cheated the speed of its movements. "We tried something really wacky: we slowed him way down and made him move like he was so damn huge and fat, but we made his footsteps really far apart. Now he could take a twenty-foot step, but that created other problems. In order to take such long steps, he had to crouch down, but we wanted him to look as big as possible in the frame. If he got too low, it started to cram him down, and if he got too high it didn't make sense for him to be taking such big steps! It took us weeks to figure this stuff out, not to mention the motion of his tail, but when we were done, all of a sudden, the shot worked. We showed our experiment to Spielberg and he said, 'That's it! That's it!'"

With the motion problem settled, the dinosaur had to be married to the background — a difficult proposition considering that the plate had been shot from the back of a moving truck. "That was a very ambitious background plate," Dippe smiles. "We wanted to create a shot that felt like you're riding in the jeep and the camera's looking over your shoulder as you're thinking, 'Look at that animal!' We couldn't use the Tondreau motion-control system in this case because it only works when the axes of movement are precisely known; we'd have had to use dolly tracks and special tilt-pan heads so the computer could record the camera's positions. We didn't want to shoot a static plate with motion control and then do some silly thing like add shake to it. We wanted to get the feeling of a jeep really driving down the road.

Herds of dinosaurs were seamlessly meshed with natural environments in the film's scenic shots.

"In the old days, we worried a lot about having steady cameras when we wanted to put an animated object into the frame; that object had to move with every jiggle in the background plate or it would look fake," Dippe adds. "But because we were using CG effects and digital compositing, I felt we should just shoot the jeep with some sort of in-frame reference to serve as a guideline for plotting the movement of each frame. In this case, we carefully placed little glowsticks, like landing lights, on the ground at precise increments on location. Once the background plate was scanned in, we then matched the movement of our two cameras by building a virtual set in the computer that perfectly duplicated the background plate, including the glowsticks. We then took one frame of the real picture and put it up on the screen and moved the computer camera around until the computer glowsticks lined up with the real ones. We did that for every eighth frame, and then we went in and matched frames as needed until the computer camera moved in sync with the real camera."

It took almost three weeks to match the computer camera's movements to those of the real camera for the jeep chase sequence, but the shots rank among the most ambitious freehand camera moves ILM has ever tackled. The result is as seamless as a shot of a charging rhino chasing a team of photographers in a nature documentary. In the realm of the computer, the distinction between reality (the background plate) and effects (computer animation) becomes quite blurred. "In reality, you have a real camera, a real set and real actors," Dippe explains. "In the computer, we have a computer camera, a virtual set and digital actors. Once the background plate is scanned into the computer, the computer camera becomes the same as the real camera, the virtual set becomes the same as the real set, and the real actors and our digital actors interact. We place our lights in the virtual set in the same place as the real lights, shining in the same direction and the same color. It's funny, but it's really a physical thing. We're directing a world of living creatures and physical objects that exist on our screen."

One of the advantages of this system is that getting another take is almost as simple as asking your dinosaur actor to back out of the shot and try it again. "That's the way I think about it," Dippe says, "but it actually takes overnight to compute. We set it all up on our virtual set, position our lights and then say, 'Okay, dinosaur, move a little faster now, crouch down a little lower and open your mouth four frames earlier!' I really just think that way, but then we have to go in with our mouse and select that stuff and run it, which usually takes at least an hour or two. On the other hand, if these were stop-motion shots, we'd have to redo the whole shot from the start, one frame at a time, and that could take days or weeks."

Once an image is in the digital realm, adding effects is akin to working with film on the atomic level, altering pixels — the essence of film — to create perfect images. In the computer, adding a dinosaur to a background plate means transmuting the pixels that once contained background information into dinosaur pixels; the process is seamless and undetectable. "In the old days when we did optical printing," Dippe recalls, "if we wanted to put forty spaceships together to make a dogfight, we'd have to expose spaceship number one on the negative, then add spaceship number two to the same negative, and so on. That negative had to run through the optical printer forty times, and if we screwed up anywhere in the process, we'd have to start from zero. That was part of the magic of the old ILM. On some of the *Star Wars* films, they did composites of upwards of forty elements, which in the optical printing world is almost mystical. Digitally, if we got the first twenty layers right but screwed up number twenty, we'd just redo the twenty-first layer and continue on. It's a totally transparent process."

The jeep chase sequence was a textbook of layered levels of CG animation. "After we added the primary dinosaur animation to the plate," Dippe says, "we then layered in the debris and dirt kicked up by his feet, some CG branches that were flying and some debris explosions after he busts through the log. We also removed some flares caused by light shining through the trees. This was all done totally digitally before we went out to film again, and for any given situation, we could go back in and change one frame and the rest would stay intact, which is another advantage over optical printing. We shoot film, scan it into the computer, take out what shouldn't be there, add what's missing and then film it out."

One of the more demanding sequences was the gallimimus chase, wherein Dr. Grant and two children flee a stampeding herd of ostrich-like dinosaurs which eventually catch up to, run around and pass our heroes. As in the jeep chase, several plates contained ambitious freehand camera moves. "Photographically and directorially, shots like these create the feeling that you're actually there," Muren crows. "I hope you never get a sense that we stepped back because we were doing an effect,

or that we locked off our shot and added a little pan. It was much freer. I hope that you get the feeling that we were temporarily able to control these animals — that we put one camera here and the other camera over there and then the animals charged in on cue and we just rolled film! For the gallimimus chase, we had Steadicam shots running along with the actors as the herd was passing them, just the way you'd shoot it if it were happening for real. I hope the film looks like everything was a little bit dangerous."

While Steve Price animated the shot of the T-rex who, as it turns out, caused the gallimimus herd to charge our heroes, the task of animating the other herd shots fell to Eric Armstrong and Don Waller. Waller's background had been in the field of stop-motion animation, where he was considered a rising young star. For *Jurassic Park,* he had to master the computer in a hectic two-month period prior to beginning work on the film. "It was like learning a new language," he observes. "Overcoming the x-y-z plane while looking at a two-dimensional monitor and getting used to doing animation with a mouse, instead of reaching in and grabbing a puppet, were the biggest challenges I faced on the shots I worked on."

Waller was surprised to discover that the processes of stop-motion and computer animation were more alike than he thought. "A stop-motion animator has a fleshed-out puppet right there in front of him with the lighting and everything," he says, "while with CG, we're actually animating wireframes, then putting the skin on and adding secondary animation. The major differences between stop-motion and computer animation were that in CG, no single individual animates the puppet, and, at least in my case, I was able to animate using extreme frames and let the computer add the in-betweens. I still had to go in and tweak the

action further to get the dinosaurs to move properly, but the computer would in-between it for me about fifty percent of the way."

Waller was prepared to take advantage of computer inbetweening thanks to his cel animation background, which also helped him in terms of creating movement "cycles" for the gallimimus. In cartoon animation, motions that repeat regularly, such as running, are made up of cycles which are linked together to create the repetitive movements without having to animate every single frame. "It took Eric Armstrong and I about two weeks to figure out and animate our own versions of run cycles for the gallimimus," Waller recalls. "That way, we had two different runs, plus we could take them and further tweak them to make them look individual. We freeze-framed some ostrich footage on a videotape monitor, and then I put cels up on the monitor and traced the run cycle patterns of the ostriches a frame at a time to get an idea of how their legs moved. We also watched the stampede of the veldt animals in *King Solomon's Mines*, because Spielberg kept referring to it. We studied big herds of gazelles to see the way they turned, and Phil Tippett made comments about how these things were supposed to move."

With 24 gallis in any given shot, the stampede was fast becoming one of the more ambitious computer animation sequences ever attempted. "The hardest thing to do in these shots was to make the gallis look like they were actually running around the actors," Waller opines. Waller and Armstrong's task was aided by the computer itself, which allowed them to view the digital set from side, front and overhead perspectives, and by the efforts of fellow animator Joe Pasquale. "Joe made little floating CG balloon heads that followed each of the actors as they were running along the path. He also made a computer grid that blocked the landscape into five-foot increments like a football field, which helped us decide where in space to place our gallis."

Positioning the gallis in the shot was accomplished using 'hood ornament forms,' which resembled giant wooden chess pieces, created by Eric Armstrong. "We first arranged our hood ornaments aesthetically from the angle that the background plate was actually shot, then we went to the other angles to make sure the dinosaurs weren't in danger of passing through one another into the fourth dimension!" Waller says. "We had to make sure the gallis were spaced so there appeared to be a lot of them coming over the hill; when they did get close to each other, we had to make sure they didn't bunch up unnaturally and that they reacted as if they might collide with one another. It was funny in dailies to see the actors running from these giant chess pieces chasing them over the fields, but that way we could move our gallis around and make the arrangement look pleasing within any given shot. Once we tweaked their paths, we went in and individually tweaked the animation of each galli. Because the run cycles were already figured out, we were able to fully animate about three gallis a day in any shot. At that rate, it took about a week and a half to get a finished shot. Altogether, there were nine cuts in the sequence."

One of the great attributes for which CG is frequently praised by effects gurus is its flexibility, a quality put to the test by Spielberg's near-last-minute decision to add a sequence to his film not even hinted at in Crichton's original novel. Though no self-respecting dinosaur movie would be complete without one giant behemoth battling another, Crichton's book surprisingly lacks such a showdown. Spielberg decided to address this shortcoming well into

production. "Steven came up with the idea of a fight between the tyrannosaurus and a couple of velociraptors about a month or so before he wanted to shoot it," recalls Dennis Muren, who supervised the sequence. "He gave us some storyboards on it, but it was unclear as to how the fight would work. We did know that it had to end with one of the raptors being tossed into the T-rex skeleton in the Visitors Center.

"Once we got onto that set, Phil Tippett and I got more specific with Steven on each of the shots to get the overall blocking of the action and performances right," he remembers. "We had to pre-visualize the entire sequence, set it up and shoot it. For the final two shots, we decided that the T-rex would lower its head with the raptor on its back, whip its head around, grab the raptor's tail in its mouth, then swing it around and fling it across the room into the dinosaur skeleton. We walked through the action and he set up the cameras so the fight would be as dynamic as possible. We probably didn't spend any more than half an hour figuring out the camera angles and movement. Phil had a big cutout of the T-rex's head on a stick and we looked at it and said, 'Well, the camera can do this, then move up there and over here.' Then we timed it. We put two cameras on that shot, one locked off, the other moving, and ended up using them both. We rehearsed a dry run two or three times and then at the end of the actual shot, Michael Lantieri, who handled the floor effects, blew the T-rex skeleton up. We got it in one take."

Of course, the background plate for that scene simply shows a tyrannosaurus skeleton crashing to the ground. Animator Steve Price added the missing velociraptor careening into the bones at precisely the right moment, as well as the enraged tyrannosaurus. "That was just a matter of knowing we had to get from here to there," Muren says of the raptor toss. "But that's nothing compared to trying to make these things look like living, moving creatures. In this final sequence, we have a CG tyrannosuarus coming down within four feet of the camera lens, shaking the raptor in his mouth, then tossing him twenty-five feet in the air. That was done all in one shot with the camera panning around! And that's what I was going for on *Jurassic Park:* when you see shots where these creatures aren't hiding behind something, but are right there in your face, those are ours."

Despite the obvious advances offered by digital technology, Muren, who has labored in the field of computer-generated effects longer than just about anyone, knows all too well how quickly such cutting-edge imagery becomes passé: "I'm not sure how this stuff is going to age, because we're starting out with something that's so strong. Maybe we'll look back in ten years and notice that we left things out that we didn't know needed to be there until we developed the next version of this technology. One thing's for sure: we haven't seen the end of this. When I set up *T2,* I said, 'I haven't found the wall yet,' and I still haven't found it. There may not be one."

Like the scientists in *Jurassic Park,* the brains at ILM have taken their science to a level even they can't quite conceive. This next evolutionary plane promises incredible new vistas which will all reside in the realm of the computer. But in planting this seed, ILM may well sow the roots of its own obsolescence. Eventually, the wizardry of *Jurassic Park* will be available to everyone with a personal computer. Of course, developing the talent to use it imaginatively is another matter indeed.